

Factors affecting rate of reaction

What is the effect of the concentration of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) on the rate of reaction with Hydrochloric Acid (HCl)?

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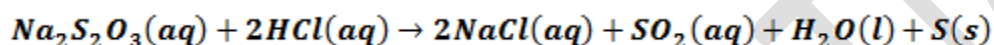
Checked and assessed by Michael Ng

Research question

What is the effect of the concentration of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) on the rate of reaction with Hydrochloric Acid (HCl)?

Introduction

In this experiment, sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) is the source of the thiosulphate ions, and hydrochloric acid will be used as the source of hydrogen ions. The chemical reaction between sodium thiosulphate and hydrochloric acid results in sulphur being precipitated slowly. The equation is as below,



Sulfur dioxide is a gas at room temperature, but is very soluble in water. Sulfur is a water insoluble solid. As a result, the solution first becomes cloudy and then opaque.

In this reaction, sulphur was formed a very fine solid particle and causes the solution to change from colourless to yellowish cloudy. The time taken for a certain quantity of sulphur to form and cause the 'O' mark to disappear is used to determine the rate of reaction.

$$\text{rate of reaction} \propto \frac{1}{\text{time taken for the mark X to disappear}}$$

The exact amount of sulphur is not measured but I assumed that quantity of sulphur will be produced in order to obscure the 'O' mark on the filter paper below the conical flask is the same.

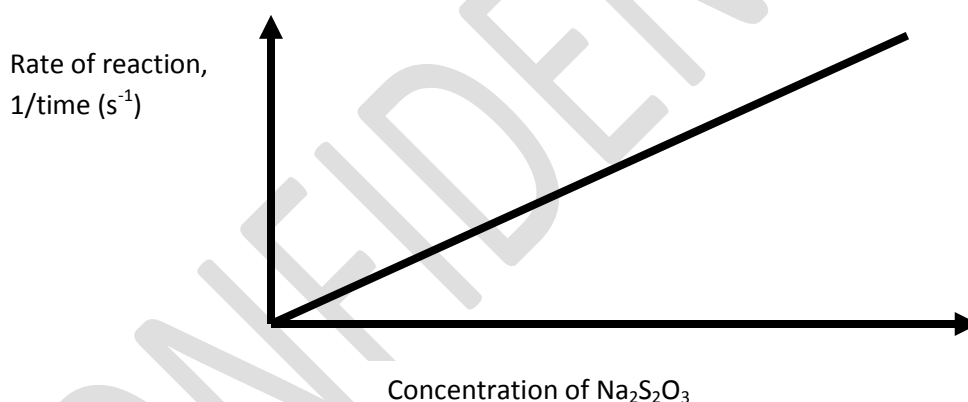
I varied the concentrations of the sodium thiosulphate to investigate its effect on the rate of the reaction with hydrochloric acid.

Hypothesis

Increasing the concentration of the sodium thiosulphate means that there will be more particles per dm^3 of this substance.

The more particles that there are in the same volume, the closer to each other the particles will be. This means that the particles collide more frequently with each other and the rate of the reaction increases.

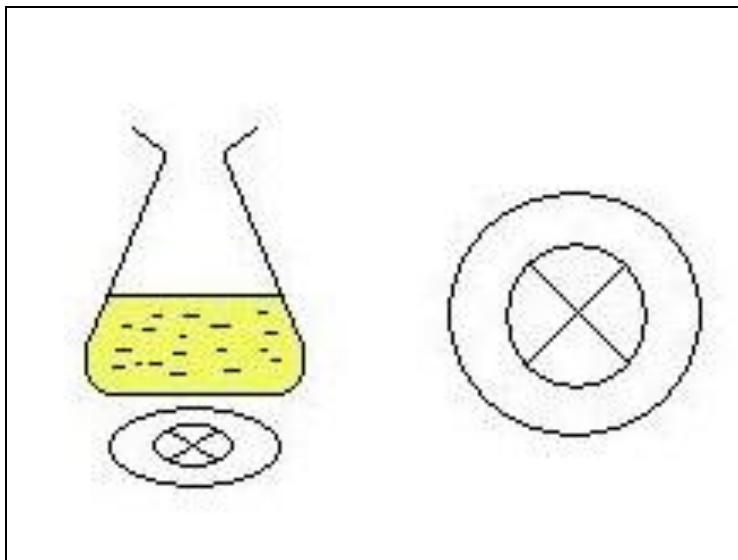
So, when the concentration of sodium thiosulphate increasing, the rate of reaction will increase, the less time taken for the 'O' mark to disappear. Supposedly, the graph that I will plot at the end of the experiment based on the data that I obtained will be like this-



Based on my intellectual assumptions, **the order of reaction with respect to sodium thiosulphate is one** because the graph of Rate of reaction versus concentration of sodium thiosulphate shows the linear relationship.

Apparatus and Materials

250 cm³ conical flask, 25 cm³ measuring cylinder, 100 cm³ measuring cylinder, filter paper with 'O' written on the paper, stopwatch, glass rod, 100 cm³ hydrochloric acid, HCl 1.0 mol dm⁻³; 500 cm³ sodium thiosulphate, Na₂S₂O₃ (aq) 1.0 mol dm⁻³, distilled water,



Variables

Independent Variables- The **concentration** for sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) are the independent variable in this experiment.

I vary the sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) concentration from 0.5 mol dm^{-3} , 0.4 mol dm^{-3} , 0.3 mol dm^{-3} , 0.2 mol dm^{-3} and 0.1 mol dm^{-3} . These concentrations will be made from dilutions of the 0.5 mol dm^{-3} sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) solutions that are provided I choose this range of concentration because I want the sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) be in excess in this reaction. This is because I want the amount of sulphur that was produced is enough to cover the 'O' mark. The dilutions are as follows:

Concentration of ($\text{Na}_2\text{S}_2\text{O}_3$) , M/ mol dm^{-3}	Volume of 0.50 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3$, $V_{\text{Na}_2\text{S}_2\text{O}_3} / \text{cm}^3$ ($\Delta V_{\text{Na}_2\text{S}_2\text{O}_3} = \pm 0.05 \text{ cm}^3$)	Volume of Distilled Water, $V_{\text{H}_2\text{O}} / \text{cm}^3$ ($\Delta V_{\text{H}_2\text{O}} = \pm 0.05 \text{ cm}^3$)
0.10	10.00	40.00
0.20	20.00	30.00
0.30	30.00	20.00
0.40	40.00	10.00
0.50	50.00	0.00

Table 1 : Preparation for ($\text{Na}_2\text{S}_2\text{O}_3$) solution with different concentration.

Two measuring cylinders were used in this case: one for the distilled water and the other for the 0.50 mol dm^{-3} sodium thiosulphate solution (to reduce inaccuracy of concentration). For example in preparation for the 0.40 mol dm^{-3} , I measure 40.00 cm^3 of sodium thiosulphate using measuring cylinder and using the dropper at the end the measurement to get just the right amount. Then I use another measuring cylinder to measure 10.00 cm^3 of distilled water and I also use dropper again so to get the correct amount. There is no need to mix the solution at this point – it will mix thoroughly as it is poured into the conical flask. The volume reading was taken from the bottom of the meniscus of the liquid. I also make sure that all the liquid was emptied from measuring cylinder. The water and sodium thiosulphate solution were poured into the conical flask and mixed thoroughly before the HCl solution was poured into the conical flask.

Dependent Variable- Time taken for the 'O' mark cannot be seen is the dependent variable in this experiment.

I used digital stopwatch to take time for the 'O' mark cannot be seen. I will call this value as time, t and it will measure in second, s. The time will start after I put the 10 cm^3 of HCl in the conical flask that have the sodium thiosulphate solution. After I started the stopwatch, I observed the 'O' mark at the top of the conical flask mouth. Care was taken to ensure that my eyes were parallel and straight with the 'O' mark. When the 'O' mark was completely cover by yellowish solid and cannot be seen, I stop the stopwatch immediately and take the reading of the stopwatch as time taken for the 'O' mark cannot be seen.

Time taken for the 'O' mark cannot be seen for each concentration was taken 2 times and average of the three reading was calculated to improve accuracy. The rate of reaction for different concentration on hydrochloric acid will be calculated by dividing 1 over the average time taken for the 'O' mark cannot be seen.

Controlled Variable- The **temperature** of the reaction, **volume and concentration of hydrochloric acid**, the **size of the conical flask** and the **size of the 'O' mark** that been used in this experiment are kept constant.

Temperature for this experiment was fixed by doing this experiment at the same place- that is the school lab. It is important to ensure that the temperature is fixed because if the temperature of the reaction were not constant, it will affect the rate of reaction.

In each of the reaction with sodium thiosulphate, I used 10 cm^3 of 1.0 mol dm^{-3} hydrochloric acid. I measure the volume for each HCl that was been used in every reaction by using measuring cylinder and dropper. The HCl solution was produced by the lab assistant, and in this experiment, I can assume that the concentration is accurate 1.0 mol dm^{-3} because the instrument that was been used to make this HCl are very accurate. There was a safety issue that need be considered. If I choose a very high concentration for HCl, it is difficult to handle the solution and it is very dangerous to do this experiment at school lab

I used the 250 cm^3 conical flask in every reaction to ensure that the size of the conical flask is the same.

The size of the 'O' mark was fixed to be 5 cm diameter. It is to ensure that the same area of 'O' mark is being used in each reaction.

All this factors are strictly controlled to ensure that my experiment is accurate.

Procedure

1. The apparatus was set up as shown in the diagram above.
2. 5cm x 5cm size of 'O' mark was drawn at a piece of filter paper.
3. 50 cm³ sodium thiosulphate, Na₂S₂O₃ 1.0 mol dm⁻³ was measured using a 50 cm³ measuring cylinder (using the dropper at the end to get just the right amount) and poured into a conical flask. Care was taken to ensure that the volume were accurate with the burette reading taken from the bottom meniscus. It also important to ensure that my eyes were parallel with the meniscus to get accurate reading.
4. The conical flask was placed on top of a piece of filter paper with an X marked on the paper. It is important to ensure that the 'O' mark is in the range of the conical flask bottom to ensure that the sulphur that was produced will cover the 'O' mark.
5. 10 cm³ hydrochloric acid, HCl 1.0 mol dm⁻³ was measured by using measuring cylinder (using the dropper at the end to get just the right amount) and immediately poured into the conical flask. Care was taken to ensure that the volume were accurate with the burette reading taken from the bottom meniscus. It also important to ensure that my eyes were parallel with the meniscus to get accurate reading.
6. At the same time the stopwatch was started.
7. The mixture was stirred with a glass rod.
8. The mark 'O' was observed from above the solution as show in the diagram. A yellow precipitate will slowly form at the base of the conical flask.
9. The stopwatch was stopped as soon as the 'O' mark was not seen. The time taken for the 'O' mark cannot be seen, t was recorded.
10. The mixture in the conical flask is poured into the sink and the conical flask was washed.
11. Step 1 to 10 was repeated one more times to get 2 sets of result reading for the time taken for the 'O' mark cannot be seen. The average time taken for the 'O' mark cannot be seen was calculated.
12. Step 1 until 11 was repeated by using different 6 volumes of sodium thiosulphate and distilled water as shown in the Table 1 to vary the concentration to 0.40 mol dm⁻³, 0.3 mol dm⁻³, 0.2 mol dm⁻³ and 0.1 mol dm⁻³.

Data Collection

This is the raw data that I got after doing all the procedure in this experiment:

Concentration of (Na ₂ S ₂ O ₃), M/ mol dm ⁻³	Time taken for the 'O' mark cannot be seen, t/s (±0.20s)	
	Trial 1	Trial 2
0.10	50.06	49.97
0.20	25.81	25.91
0.30	20.43	20.19
0.40	15.09	15.25
0.50	13.31	13.12
Qualitative Observation <ul style="list-style-type: none"> Sodium thiosulphate solution, hydrochloric acid solution and the distilled water were colourless. When hydrochloric acid was added to the sodium thiosulphate solution in the conical flask, sulphur is formed and causes the solution to change from colourless to yellowish cloudy. When the concentration of sodium thiosulphate is high the X mark can clearly be seen, but as soon as the concentration of sodium thiosulphate is progressively diluted, the X mark slowly disappears. 		

Table 2: Raw Data for time taken for the 'O' mark cannot be seen

Uncertainties

Concentration of $(\text{Na}_2\text{S}_2\text{O}_3)$, $\text{M}/\text{mol dm}^{-3}$	Volume of $0.50 \text{ mol dm}^{-3} \text{Na}_2\text{S}_2\text{O}_3$, $V_{\text{Na}_2\text{S}_2\text{O}_3} / \text{cm}^3$ $(\Delta V_{\text{Na}_2\text{S}_2\text{O}_3} = \pm 0.05 \text{ cm}^3)$	Volume of Distilled Water, $V_{\text{H}_2\text{O}} / \text{cm}^3$ $(\Delta V_{\text{H}_2\text{O}} = \pm 0.05 \text{ cm}^3)$	Total Error for Concentration of $\text{Na}_2\text{S}_2\text{O}_3$ %
0.10	10.00	40.00	0.63
0.20	20.00	30.00	0.42
0.30	30.00	20.00	0.42
0.40	40.00	10.00	0.63
0.50	50.00	0.00	0.63

The smallest division on a measuring cylinder scale is 0.1 cm^3 . So, I assume that the instrumental uncertainty for measuring cylinder that I used is 0.05 cm^3 . I neglect the uncertainty for the mass of the sodium thiosulphate that were used to make the 0.5 mol dm^{-3} because it was not provided and the smallest scale of the weighing machine is very small, 0.0001 g . So after I added all the percentage of uncertainty for the concentration of sodium thiosulphate, the uncertainties is $0.0001 \text{ mol dm}^{-3}$. This will be an insignificant uncertainty because it is so small and I can neglect it.

For uncertainties of time, I took the difference between the maximum and minimum time that I get for each height and I will sum it up and took the average. The average value that I get will be considered as the uncertainties for time. The reason I take this value is because there was a random error that need to be considered when I doing this experiment.

Concentration of (Na₂S₂O₃), M/ mol dm⁻³	Maximum time taken for the 'O' mark cannot be seen, t/s (±0.20s)	Minimum time taken for the 'O' mark cannot be seen, t/s (±0.20s)	Difference in time taken for the 'O' mark cannot be seen, t/s (±0.20s)
0.10	50.06	49.97	0.09
0.20	25.91	25.81	0.10
0.30	20.43	20.19	0.24
0.40	15.25	15.09	0.16
0.50	13.31	13.12	0.19

Table 3: The value for time difference

The total difference for all time taken for the 'O' mark cannot be seen is 0.78 s. The average difference for time for each height is:

$$\begin{aligned}\text{average difference} &= \frac{\text{Total difference}}{5} \\ &= \frac{0.78s}{5}\end{aligned}$$

$$\text{average difference} = 0.16s$$

The average difference for time at each height is 0.16 second. So, I rounded it up to 0.20 second and make it as the uncertainty for time. This value seems very reasonable because I consider the random error that cause by human (that is me- maybe) and also the uncertainty for the instrument (stopwatch) itself which is 0.1 second.

Data Processing

To find the average time taken for each time, I used this formula,

$$T_{average} = \frac{T_1 + T_2}{2}.$$

The rate of reaction for different concentration on hydrochloric acid will be calculated by dividing 1 over the average time taken for the 'O' mark cannot be seen.

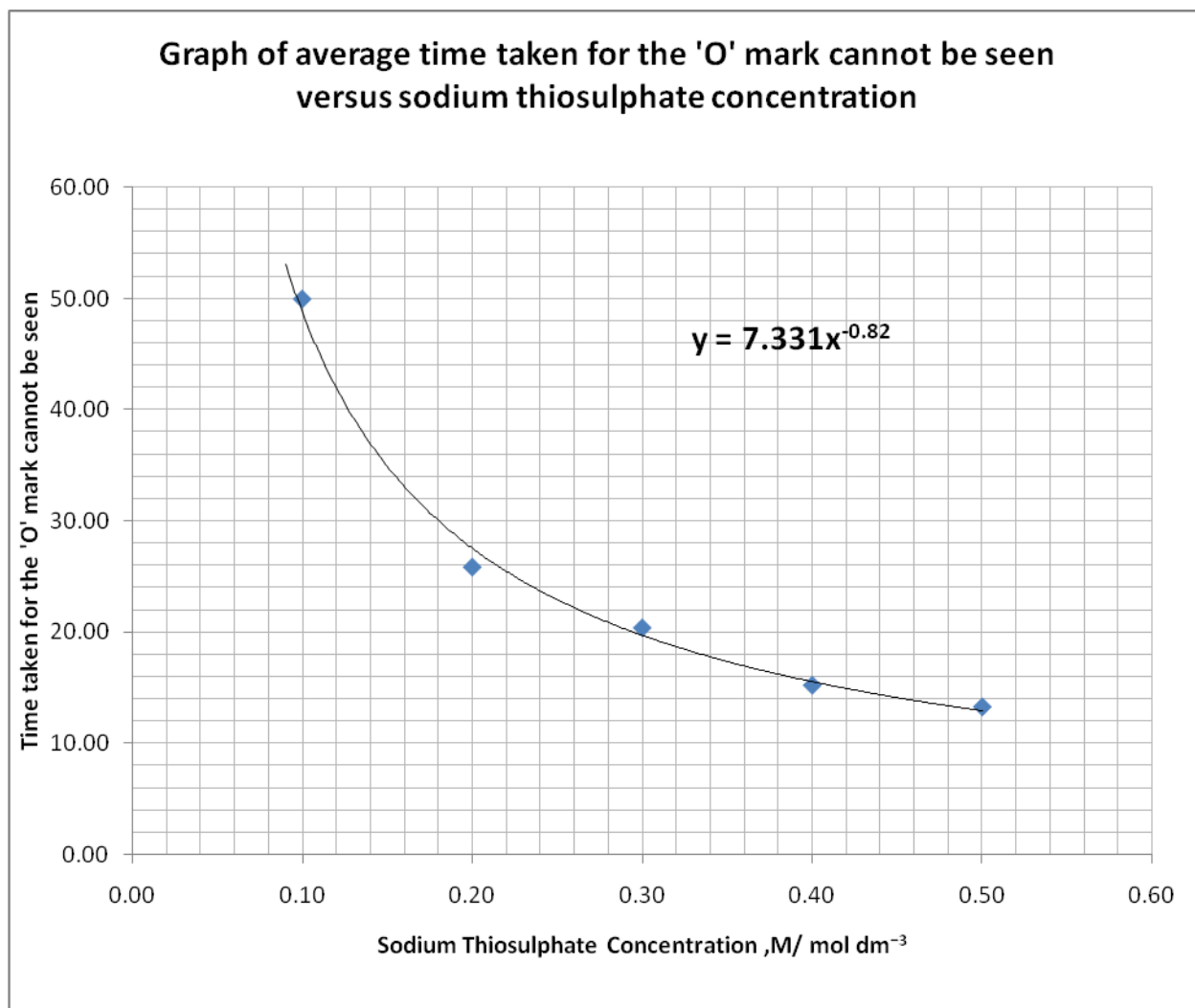
$$\text{rate of reaction} = \frac{1}{\text{average time taken for the 'X' mark cannot be seen}}$$

I'm using Microsoft Excel to done this calculation.

Concentration of (Na ₂ S ₂ O ₃), M/ mol dm ⁻³	Average time taken for the 'O' mark cannot be seen, t/s (±0.20s)	Rate of reaction for Na ₂ S ₂ O ₃ with HCl, 1/t (±0.001s ⁻¹)
0.10	50.02	0.020
0.20	25.86	0.040
0.30	20.39	0.050
0.40	15.22	0.070
0.50	13.27	0.080

Table 4 : Average time taken for the 'O' mark cannot be seen and rate of reaction

After I get all the data that I needed, I plotted two graphs to get the information about the reaction time and also the reaction rate. The first graph that I plotted is the **graph sodium thiosulphate concentration versus time taken for the 'O' mark cannot be seen**. I plot this graph using Microsoft Excel 2007.



Graph 1 : Graph of average time taken for the 'O' mark cannot be seen versus sodium thiosulphate concentration

Analysis of Graph 1

Graph 1 is a curve graph where the gradient of the curve is steep at the beginning and progressively becomes horizontal when the concentration is increasing.

Based on the Graph 1 that I plotted, when the concentration of sodium thiosulphate lowered, the time taken for the 'O' mark cannot be seen will be longer. This means that the rate of reaction is lower. Graph 1 show that the concentration is inversely proportional to average time taken for the 'O' mark cannot be seen.

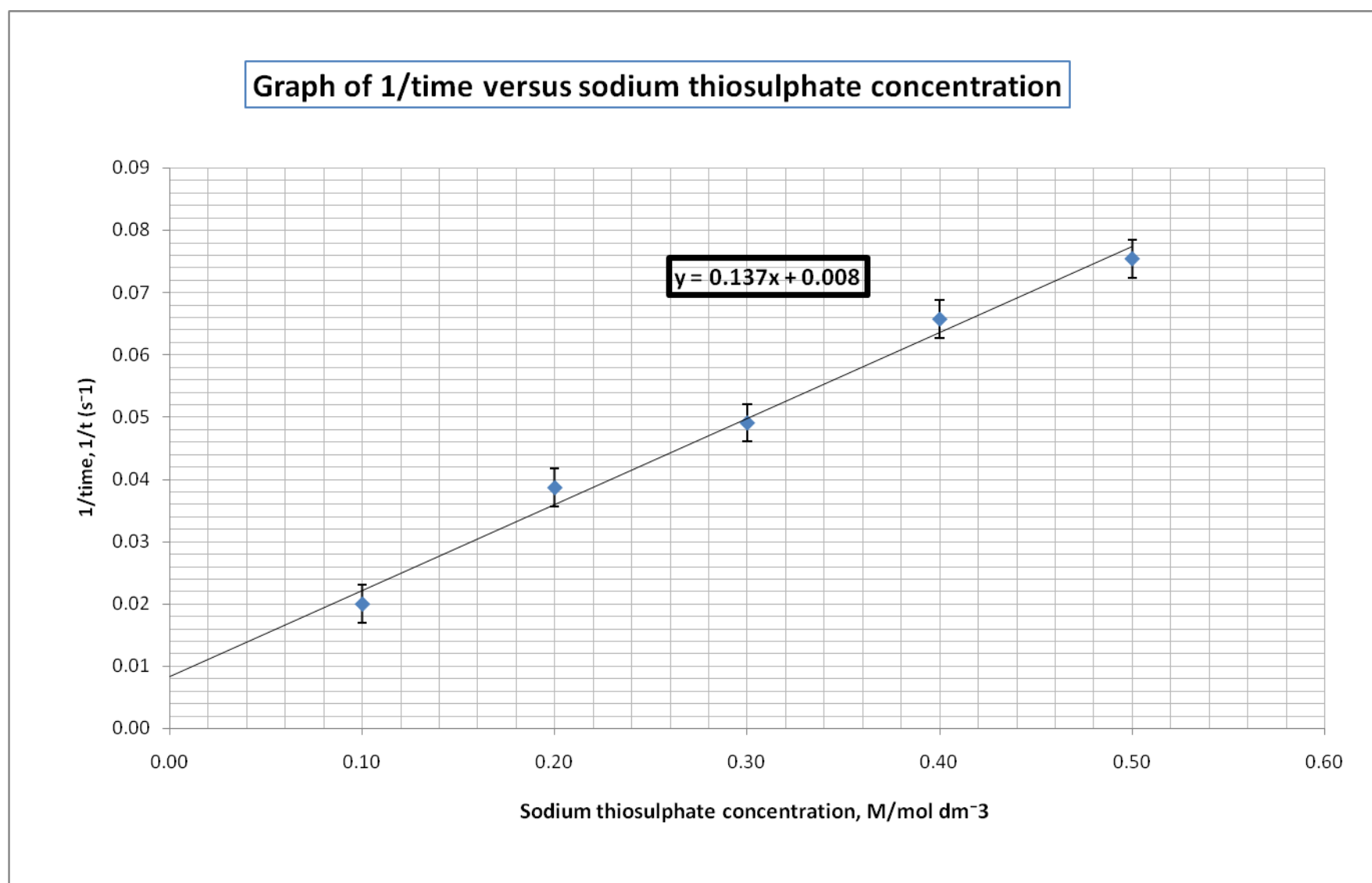
So, to get the straight line graph, I need to plot the graph of 1/time taken for the 'O' mark cannot be seen versus concentration of sodium thiosulphate.

Before I plotted the graph, I need to find the value of 1/time of all my average time and also its uncertainty. So I make a table for time, 1/time and also its uncertainty.

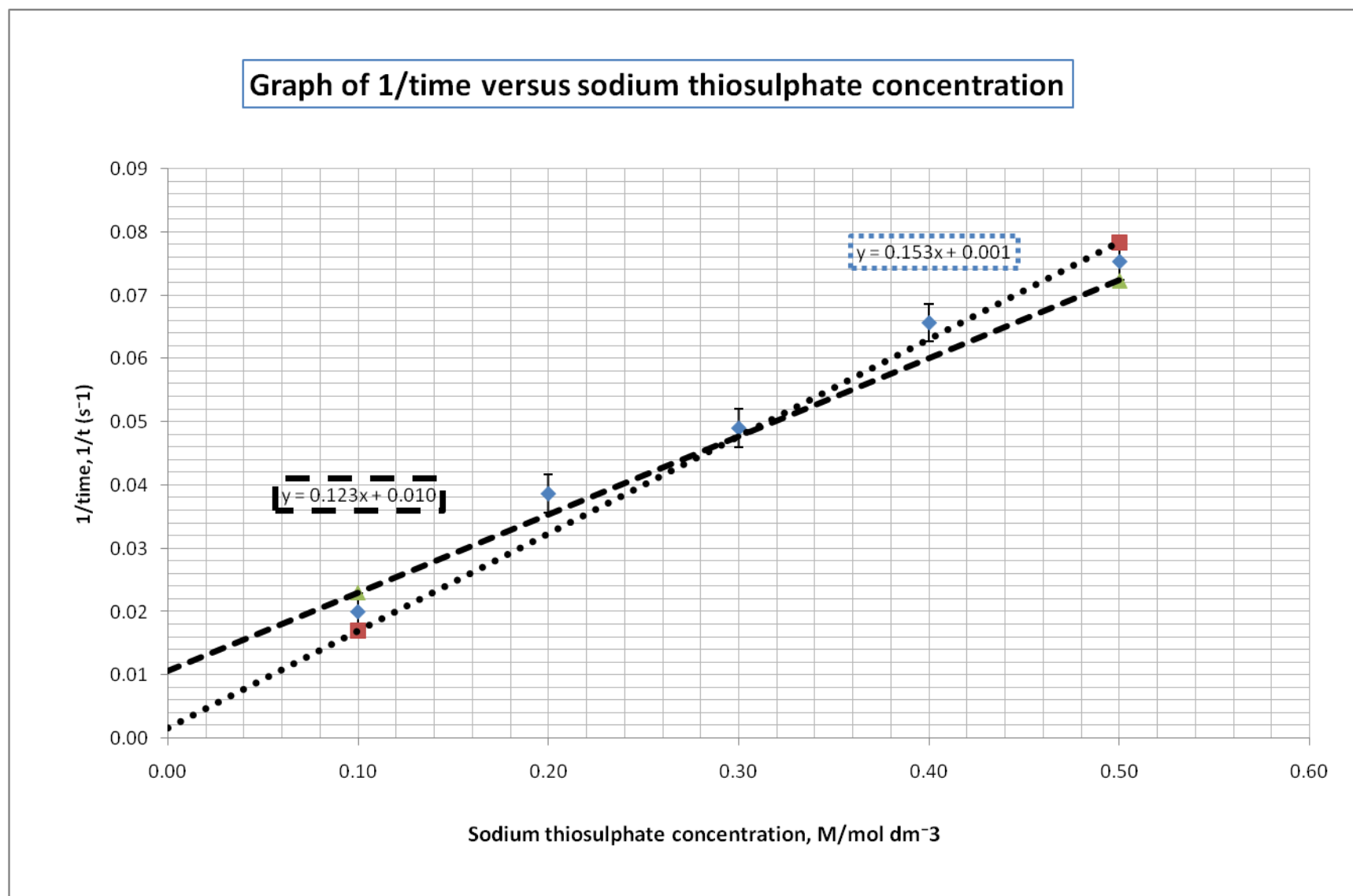
Average time taken for the 'O' mark cannot be seen, t/s (± 0.20 s)	Rate of reaction for $\text{Na}_2\text{S}_2\text{O}_3$ with HCl, 1/t ($\pm 0.001\text{s}^{-1}$)	% uncertainty for time, $\% \Delta t$ $\left[\frac{0.2}{\text{time}} \times 100 \right]$	% uncertainty for 1/time, $1/\Delta t$ $[\% \Delta t \times 1]$	Uncertainty for 1/time $\left[\frac{\% \Delta t \times 1/t}{100} \right]$
13.27	0.08	1.51	1.51	0.001
15.22	0.07	1.31	1.31	0.001
20.39	0.05	0.98	0.98	0.001
25.86	0.04	0.77	0.77	0.001
50.02	0.02	0.40	0.40	0.001

Table 4 : Uncertainty for time squared

The uncertainties for the 1/time in the graph that I was plotted were based on the value for uncertainty for time square for each different heights based on the table 4. All the calculation for the uncertainty was done using Microsoft Excel 2007.



Graph 2: Graph of 1/time versus sodium thiosulphate concentration (best fit line)



Graph 3: Graph of 1/time versus sodium thiosulphate concentration (steepest and shallowest lin

Analysis of Graph 2 and 3

From the best fit line graph (Graph 2) that I plotted using Microsoft Excel 2007, I can see that the best fit line did not touch the origin. I suspect that there must be some mistake about my graph equation, but after I consider the uncertainty and plotted the steepest and shallowest line based on the uncertainty (Graph 3), the line was still above in the range origin. So, I suspected that there must be some systematic errors that shift the graph up 0.008 units. I will discuss the systematic error in the evaluation part.

Almost all the point that I have plotted for the best fit line also touches the line. It shows that the correlation for my graph is almost to 1.

Graph 2 is a straight line where the concentration of sodium thiosulphate is proportional to the rate of reaction ($\frac{1}{\text{time}}$). This also indicate that the order of reaction respect to sodium thiosulphate is one.

CONCLUSION

The aim for this investigation is to investigate what is the effect of the concentration of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) on the rate of reaction with Hydrochloric Acid (HCl). In my hypothesis statement, I stated “when **the concentration of sodium thiosulphate increasing, the rate of reaction will increase, the less time taken for the ‘O’ mark to disappear.**” For this statement, my hypothesis is proven true because when I plotted the graph of rate of reaction versus concentration of sodium thiosulphate, the time will decrease when the concentration was increased. The second statement in my hypothesis stated that when I plotted the graph of rate of reaction versus concentration of sodium thiosulphate, “**it will be directly proportional**” is proven true because the relationship was linear because the graph shows a straight line. I conclude that it is directly proportional because when I consider the uncertainty for the best fit line and also 0.008 shift form systematic error, it includes the origin. Based on my hypothesis, “**the order of reaction with respect to sodium thiosulphate is one**”. This statement also was proven true because based on the graph 2 that I plotted, it is a straight line where the concentration of sodium thiosulphate is proportional to the rate of reaction($\frac{1}{\text{time}}$).

Nevertheless, the aim for this experiment is to find what is the effect of the concentration of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) on the rate of reaction with Hydrochloric Acid (HCl). And I have found it- **the order of reaction with respect to sodium thiosulphate is one**. It is a great success for me to find this relationship.

EVALUATION AND WAY OF IMPROVEMENT

There were some problems when I was doing this experiment and these errors have produced a huge percentage of uncertainty in my experiment.

1. I suspect that there was systematic errors occur in this experiment because the best fit line graph was shifted to 0.008. This condition occur maybe because the 'O' mark that I used is big in size and this leads to more time taken for the 'O' mark to disappear when hydrochloric acid was added to sodium thiosulphate. In the future experiment, I should use a more suitable size of 'O' mark that can really suit with the base of the conical flask.
2. When I stirred the sodium thiosulphate and hydrochloric solution in the conical flask with the glass rod, the rate and number of stirring is not constant and it affects the time taken for the 'O' mark cannot be seen. In the future experiment, maybe I can use magnetic stirrer to make my stirring process become constant.
3. It was also hard for me to observe when the 'O' mark completely cannot be seen. A light sensor could be used in this experiment to measure the penetration of light that pass through the solution. It would be more accurate this way because I can really observe when the sulphur is formed and cover the entire conical flask base.
4. Due to the time factors, I only can do two trials for each of the sodium thiosulphate solutions. So, in the future experiment, I can do more trials to get more results to eliminate the random errors.